LA-UR-77-1872

TITLE: SUB-PICOSECOND PROXIMITY-FOCUSED VISIBLE STREAK CAMERA EVALUATION AND APPLICATION

Conf-770814--2

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SUBMITTED TO: S.P.I.E. Meeting, San Diego, CA, August 25-26, 1977

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CONTRACT W-7405-ENG. 36

SUB-PICOSECOND PROXIMITY-FOCUSED VISIBLE STREAK CAMERA EVALUATION AND APPLICATION

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Abstract

Several years ago a new era in streak cameras began with the introduction of an x-ray sensitive proximity-focused streak tube. This device displayed better than 3 ps resolution and a large dynamic range, making it a fundamental laser-fusion diagnostic. The new tube is based upon parallel-photoelectron trajectories, rather than cross-over or pinhole electron optics used in virtually all other streak tubes. This eliminates a host of problems due to space charge buildup effects at the electron pinhole such as low dynamic resolution, limited dynamic range and unpredictable instrumental field distortion. In the old tube instrumental errors are related to distribution of photocathode illumination in picosecond temporal application.

Recently a visible variant of the proximity-focused tube design has been constructed. This camera displays all the advantages of its predecessor including high sensitivity, large dynamic range and a flat format making it ideal for digital readout. In addition, picosecond streaks of high statistical quality indicate the design limit has yet to be reached. The new camera has already uncovered laser oscillator problems proving its utility as a basic laser diagnostic. Using this new "photon micrometer", a myriad of new optical techniques such as high-accuracy three dimensional imaging are now possible.

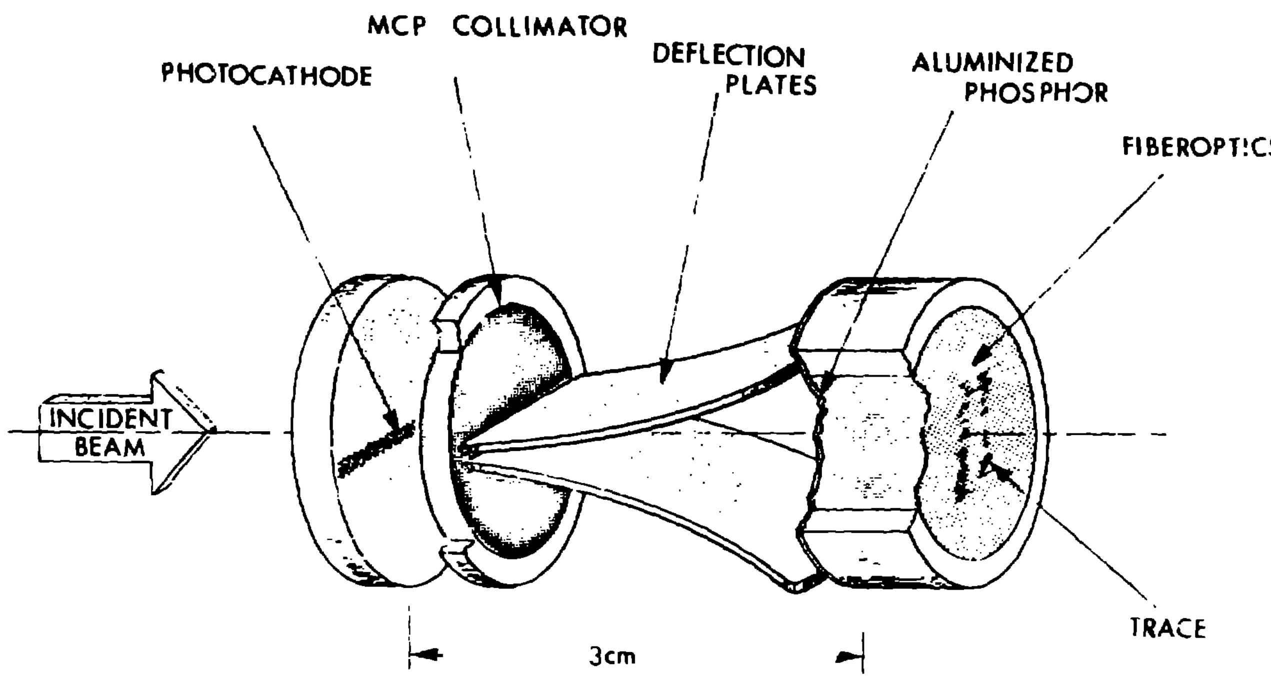
Introduction

Streak camera temporal resolution began to be pressed to design limits by the introduction of lasers capable of producing picosecond pulses and experiments associated with these devices. Over the past two decades virtually all streak cameras have used a streak tube based upon cross-over or electron pinhole optics. Through the years this tube has been upgraded by the addition of extraction grids, special photocathodes, and the use of follow-on amplifiers. However, when pressed to the temporal limits of true picosecond resolution for x-ray laser-fusion experiments and simple laser diagnostics, the electron optics precludes production of high-resolution picosecond streaks over a wide range of input signals. In laser-fusion applications, instabilities of less than 2 picoseconds require an x-ray streak camera with at least this resolution before such instabilities can be measured and corrected. For visible recording sub-picosecond lasers require similar temporal resolution over a wide dynamic range to be a practical laboratory diagnostic.

For these reasons a new type of streak tube based upon the planar intensifier was developed and opened a new era in streak camera recording. The tube is depicted schematically in Figure 1. Complications present in the old design due to lens effects and extraction

Fig. 1. Schematic of planar streak tube. Parallel electron beam optics is used to conduct photoelectron from cathode to phosphor. Resolution is beam intensity independent and maintained by proximity focusing.

Richie


MCP COLLIMATOR
PHOTOCATHODE
DEFLECTION PLATES
ALUMINIZED PHOSPHOR
FIBEROPTICS
INCIDENT BEAM
TRACE
3cm

grids are not present since grids are not employed. Resolution problems due to space buildup at the electron pinhole are eliminated since cross-over electron optics is not used and there is no pinhole. Unpredictable instrumental errors present at picosecond and sub-picosecond resolution due to photocathode illumination effecting distortion are eliminated. A large dynamic range in excess of 500X is inherent in this type of device because basically one can deflect and conduct a much larger peak photoelectron current in a sheet rather than one can "pour" through a pinhole.

Experimental Results

The planar streak tube has proved itself as an x-ray laser-fusion diagnostic. It is the only camera capable of yielding better than 3 ps resolution over a wide range of 1-5 keV x-ray intensities. Recently the visible design derivative was introduced. It too has shown all the advantages generic to this type of tube. The planar visible streak tube was first tested using a 30 ps Nd:YAG laser. For initial tests an etalon was used to delay optically part of the beam by 7 ps. Densitometer traces of the streaks are shown in Figure 2. For these tests an inverse sweep rate of 6-7 ps/mm was used. Some

Fig. 2. Densitometer traces of two traces from a 30 ps Nd:YAG laser which are optically delayed from each other by 7 ps. For these measurements an inverse sweep velocity of 6-7 ps/mm was used. The superior conduction of the streak tube produces traces of high statistical quality which in turn yield smooth densitometer profiles.

fine structure in the beams is apparent near the pulse maximum. In Figure 3 partially silvered mirrors were used to measure not only sweep velocity but also dynamic range. In this case the inverse sweep velocity was run at 4.6 ps/mm. From these data a dynamic range of greater than 100X and instrumental resolution of 1-2 ps is evident. These data imply

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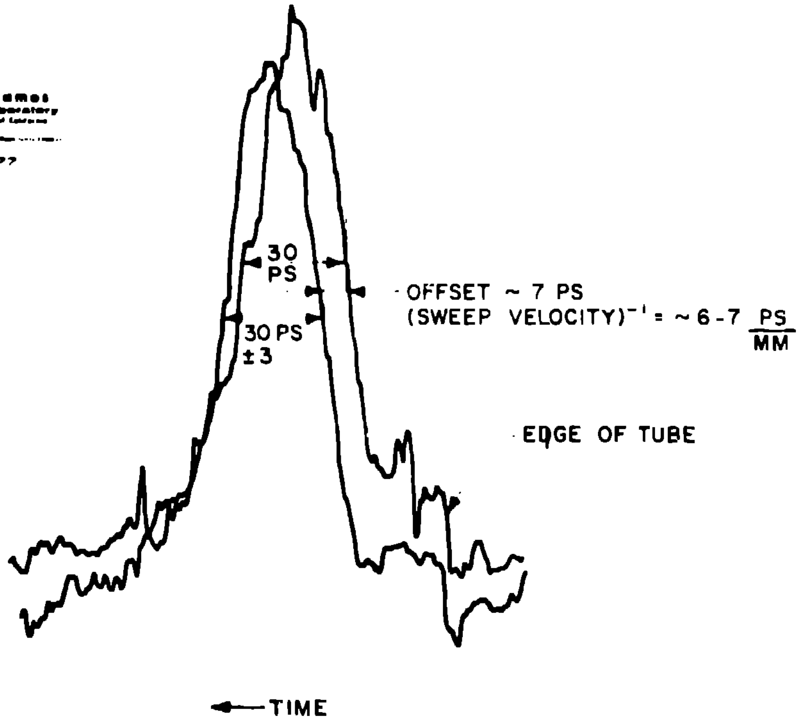
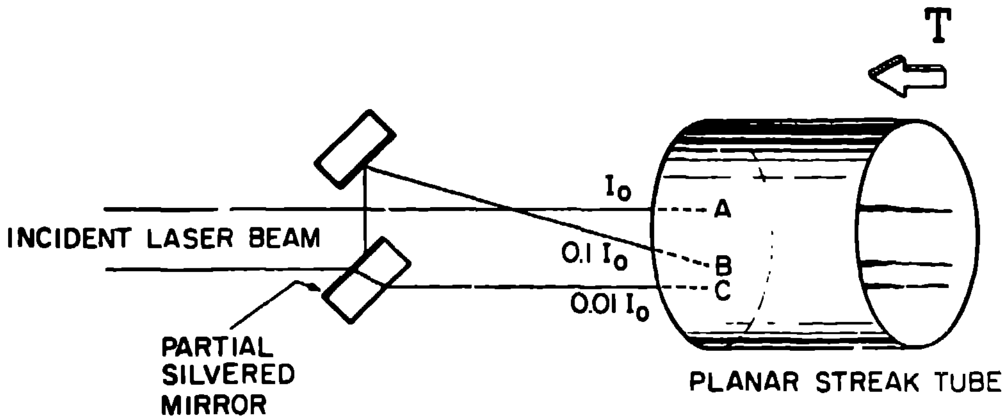


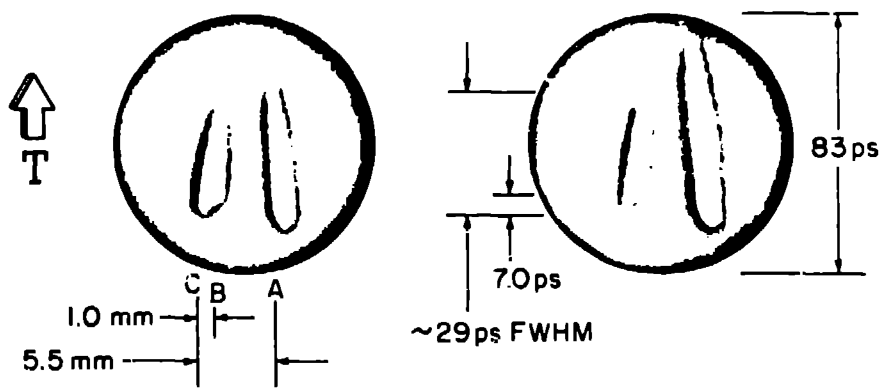
Fig. 3. Three beam intensity and timing study. For these studies a 4.6 and 8 µs/mm inverse sweep rate was used. Camera resolution for the 4.6 ps/mm rate is 1-2 ps. Streak convergence is due to field distortion in the prototype tube since the deflection plates structure is only one cm wide and has been corrected in later models to be absolutely linear and flat.

the camera will easily be capable of sub-picosecond resolution with high statistical quality streaks without pressing the design limitations.

In Figure 4 typical laser features are shown. The switched out pulses and Pockels cell bleedthrough are apparent in a single exposure. Since the extinction ratio of this particular Pockels cell is quoted as 800X this confirms a dynamic range in excess of 500X. The increase in width of the traces is due to film burnout and not due to the optics of the tube. Figure 5 shows some typical shots with the Nd:YAG laser. It is noted that for shots of 10 mJ energy or less a much slower risetime is encountered than for shots above 12 mJ.

To measure the dynamic range and maximum resolution capability of this new laser diagnostic, a much faster laser was needed. A glass laser of approximately 4 ps pulse duration is now being used together with an etalon system to determine these parameters. Results from this study will be presented at a later date.





v^{-1} = 8 ps/mm

v^{-1} = 4.6 ps/mm

τ = 1-2 ps

Dynamic range >100

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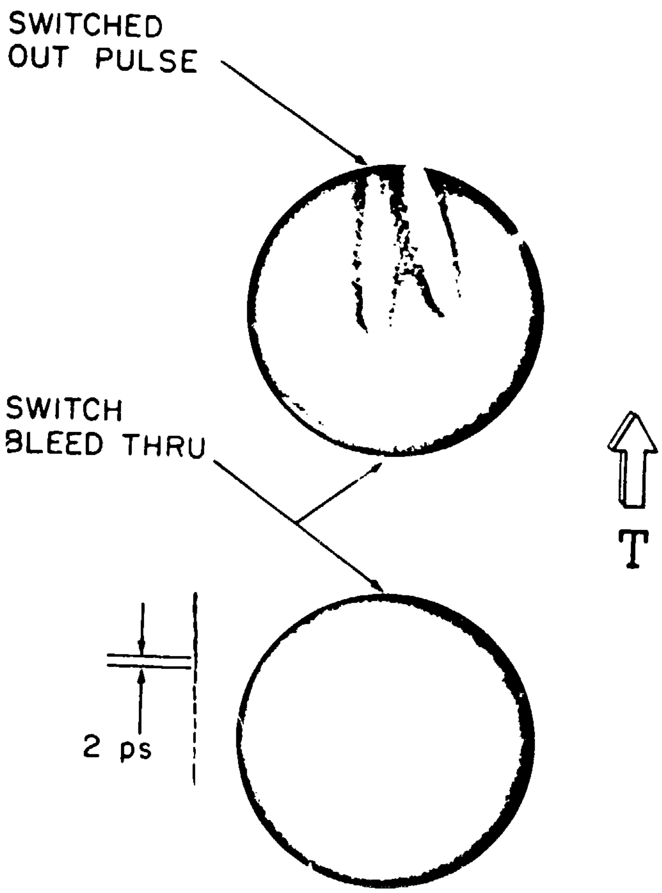
Fig. 4. Switched out laser pulse and switch bleedthrough are apparent in one exposure.

Fig. 5. Pulse profile study of a 30 ps Nd:YAG laser as a function of laser energy. The lower energy shots display a slower risetime.

Rieber



SWITCHED
OUT PULSE
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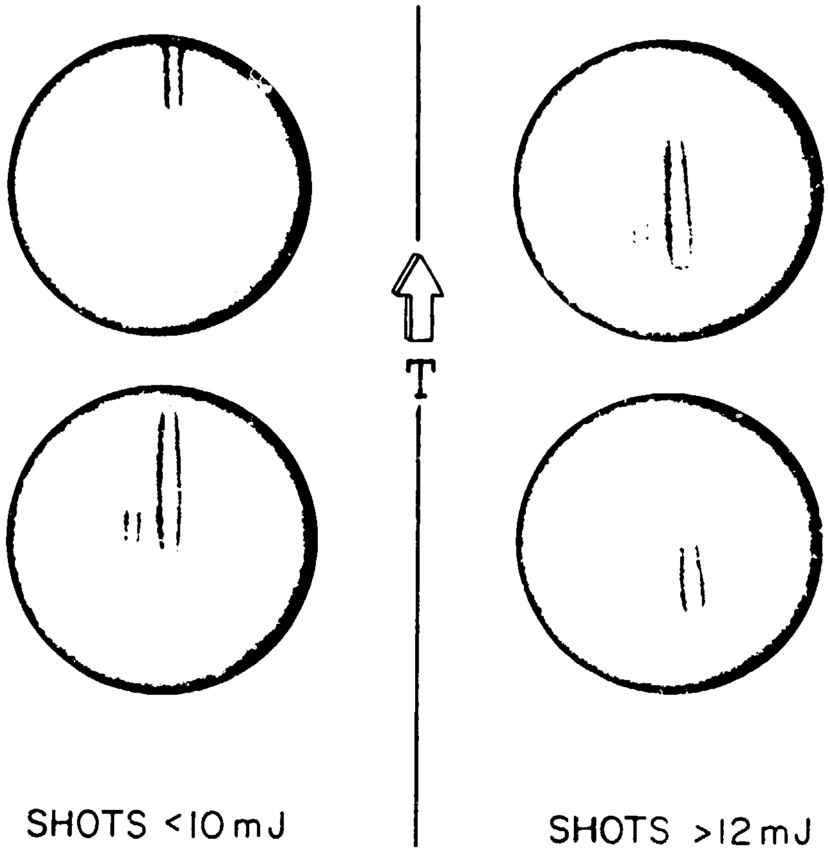
T
SHOTS <10 mJ
SHOTS >12 mJ